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ASSOCIATION PETROLIÈRE POUR LA CONSERVATION DE L'ENVIRONNEMENT CANADIEN

PACE Report No. 88-3

CANADIAN DIESEL FUEL SULPHUR COST SURVEY

Working for a Better Environment

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PACE REPORT NO. 88-3

Prepared for

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TABLE OF CONTENTS

			Page No.
1.	Executive Summary		1-1
2.	Survey		2-1
	2.1	Background	2-1
	2.2	Survey Methodology	2-5
	2.3	Current Situation	2-7
	2.4	Costs	2-12
	2.5	Timing and Constraints	2-16

APPENDICES

A.	List of Canadian Diesel Producers
B.	Guidelines for Survey
C.	Miscellaneous Calculations and Balances

TABLES

1-1	The Cost of Highway Diesel Fuel Reduction	1-3
2.2-1	Definitions	2-2 (a)
2.3-1	Current Diesel Sulphur By Producer Size	2-8
2.3-2	Current Sulphur Distribution by Producer Location	2-8
2.4-1	Summary of Producers Requiring Changes	2-12
2.4-2	Costs Associated with a 0.15% Sulphur Specification	2-13
2.4-3	Costs Associated with a 0.05% Sulphur Specification	2-14
2.4-4	Major Change Summary	2-14

FIGURES

2.3-1	Canadian Diesel Fuel Study	2-10
2.3-2	Sulphur Content of Diesel Fuel by Region	2-11

1.0 EXECUTIVE SUMMARY

The Petroleum Association for Conservation of the Canadian Environment (PACE) commissioned a survey of Canadian refineries to determine the cost impact of a possible reduction in the sulphur specification of highway diesel fuel. Consideration is being given, in both the U.S. and Canada, to a reduction from the current 0.5% normal maximum to the order of 0.05 weight percent maximum sulphur to assist in the reduction of diesel engine particulate emissions to meet 1991 and 1994 standards as set out by the U.S. Environmental Protection Agency. Transport Canada has yet to accept these particulate standards, but has endorsed new 1989 diesel engine emission standards (which can generally be met by current models of diesel engines and fuels). An intermediate sulphur level of 0.15 weight percent has also been considered here, in addition to the 0.05 level, in order to provide data on cost versus degree of sulphur reduction.

RTM Engineering Ltd. compiled the responses to a survey form distributed to Canadian companies producing diesel fuels for Canadian markets. The survey covered some 27 plants in all, primarily refineries, but also included one petrochemical plant and one oil sand upgrading plant. RTM reviewed the responses in all cases for consistency and completeness and discussed with producers as appropriate. RTM also assisted in estimating capital and operating costs at two producing facilities.

Currently only three provinces have diesel fuel standards identical or equivalent to those set by the Canadian General Standards Board (CGSB) and such standards now permit a maximum of 0.7 weight percent sulphur in Type B diesel fuels, the major diesel fuel grade. The Canadian refining industry has, however, been using a 0.5 maximum and a new CGSB standard at the same level may come into effect in late 1988.

The current Canadian highway diesel fuel sulphur content weighted average is approximately 0.2 weight percent, but ranges from 0.03 to 0.45, depending on the refinery and time of year. In order to reduce the sulphur content of highway diesel fuels, economics dictate new refinery processing facilities that will also reduce the sulphur content of non highway diesel fuels (used, for example, in the mining and forestry industries and by railways and shipping) and of a portion of the light fuel oils consumed in Canada. Eastern Canada has the bulk of light fuel oil sales and some segregation is possible for local sales and for sales in the major urban areas of southern Ontario and Quebec. In western Canada light fuel oil sales are insignificant and both there and in much of eastern Canada no tankage exists to permit segregation of diesel and light fuel oils.

Virtually all respondents indicated that it is not economically attractive to provide further segregation in the overall system. For each litre of highway diesel produced, about one litre of non highway diesel and light fuel oil will also be processed on average to allow a common product, acceptable for highway diesel fuel and other diesel and light fuel uses.

Current crude consumption patterns have been assumed in this survey. Because the survey has not attempted to consider potential changes in crude consumption, it did not factor in the impact of heavier, more sour crudes and synthetic crudes, which will be substituted as low sulfur Canadian and foreign light crudes decline in availability.

Virtually all refineries are in the midst of major projects to allow the total phase out of tetraethyl lead from Canadian gasolines by the end of 1992. While no date has been established for a possible Canadian reduction of sulphur in diesel fuel, it would appear likely to be co-ordinated with the 1991 and/or 1994 sets of United States EPA diesel engine emission standards. This timing would indicate a serious competition with the gasoline lead phase out program for funds and personnel. Overall, at least four years notice would be needed in order to accomplish a highway diesel sulphur reduction program in Canada. The overall program should allow time for diesel engine (and exhaust trap) manufacturers to optimize their design modifications before new sulphur specifications can be introduced.

To meet any new sulphur specification for highway diesel, at two small refineries, economics would favour the purchase of ultra low sulphur level diesel blending components and/or the sale of current diesel components to non highway uses with the purchase of highway quality diesel to meet local needs.

While 7 of the 25 other producers of diesel fuels, all in Western Canada, for the Canadian market now meet, or with minimal cost can meet, a 0.05 weight percent sulphur specification, the majority will require new process facilities and/or major revisions to existing desulphurization facilities. There is a pronounced difference in capital needs between 0.15 and the 0.05 sulphur contents. While the current industry maximum sulphur content standard of 0.5 weight percent maximum allows some direct use of virgin distillates, a 0.05 specification will require all diesel fuel components (with the exception of those derived directly from synthetic crude oils) to undergo hydrodesulphurization.

The new facilities required will include:

- revisions to existing middle distillate hydrodesulphurization units
- new catalyst
- added reactor capacity
- added recycle gas capacity, etc.
- new hydrodesulphurization units generally operating at temperatures and pressures above those of existing units (designed to meet the 0.5 weight percent standard)
- added hydrogen recovery facilities
- expanded, or in a few cases new, amine and sulphur recovery facilities
- new intermediate tankage will also be needed in at least two cases.

Operating costs will increase due to use of more catalyst at higher severity, increased process fuel and other utility needs, higher maintenance costs due to added facilities, added operation staff in a few cases, and increased supervision and laboratory services.

Table 1-1 provides the estimated costs, in current 1987 Canadian dollars, of reducing sulphur to both the 0.15 and 0.05 weight percent levels.

TABLE 1-1
THE COST OF HIGHWAY DIESEL FUEL REDUCTION

Highway Diesel Sulphur Specification Level	Capital	Annual Direct Operating Costs	Incremental Cost To Consumer*
wt percent	Millions of '87 Dollars	Millions of '87 Dollars	Cents per Litre of Highway Diesel++
0.15	521.3	73.5	1.7
0.05	972.3	113.5	2.9

* Includes Annualized Capital Charge averaging approximately 12% DCF rate of return after tax
++ Assumes 10,500,000 cubic meters a year of Highway Diesel Fuel consumption

*Note: Based on estimated distribution of highway diesel fuel of 58% in eastern Canada and 42% in western Canada, the regional costs for the first case (0.15%) would be 2.3 cents per litre of highway diesel in the east and 0.8 cents per litre in the west for the second case (0.05% S), the corresponding figures would be 3.8 cents per litre in the east and 1.8 cents per litre in the west.

The costs do not include any incremental sales or value added taxes. However provision has been made for income tax on the return on capital required for new facilities. The costs shown do not include added costs for several producers to buy low sulphur diesel fuel or crude oils in lieu of new capital facilities.

In the 0.05 case, the estimated cost per tonne of sulphur recovered as a result of the change in highway diesel fuel specifications is approximately $12,600. (See Appendix C.)

In our opinion, it is probable that non highway diesel fuel users, and some light fuel oil users, especially in the west and outside major urban areas in eastern Canada, will share in the added cost due to the normal commonality of product and the difficulties in distinguishing between highway and many off road uses. Diesel fuel represents the largest operating cost for a truck fleet. Hence, the Canadian economy, its transportation sector in particular, will be faced with major increases in costs.

If the allowable sulphur contents of non highway diesel fuels and of light fuel oils are reduced to the same new standard as highway diesel, there will be quite significant capital and operating costs additional to the costs discussed above.

1.0(a) SOMMAIRE

L'Association pétrolière pour la conservation de l'environnement canadien (APCE) a commandé une enquête auprès des raffineries canadiennes afin d'évaluer les conséquences financières d'une réduction possible de la teneur maximale en soufre des combustibles diesel de véhicules automobiles. On étudie, aux Etats-Unis et au Canada, la possibilité de réduire la teneur maximale en soufre du 0,5% en masse présentement en vigueur à un niveau allant jusqu'à 0,05%. L'objet serait de contribuer à la réduction des dégagements de particules par les moteurs diesel de véhicules automobiles afin de pouvoir satisfaire aux normes d'émission de particules établies pour 1991 et 1994 par l'Environmental Protection Agency (EPA) des Etats-Unis. Transports Canada, bien qu'il n'ait pas encore accepté ces normes d'émission de particules, adhère aux nouvelles normes d'émission des moteurs diesel établies pour 1989 (normes auxquelles les derniers modèles de moteurs diesel et les combustibles diesel existants peuvent généralement satisfaire). Cette enquête a également considéré un niveau intérmediaire de teneur en soufre de 0,15 % en masse afin d'etablir des données sur le rapport entre les coûts et le degré de réduction du soufre.

RTM Engineering Ltd. a compilé les réponses a un formulaire d'enquête qu'on avait envoyé aux producteurs canadiens de combustibles diesel destinés au marché canadien. La plupart des 27 installations qui ont participé à l'enquête étaient des raffineries, mais on y comptait aussi une usine pétrochimique et une usine de pré-raffinage de sables bitumineux. RTM a examiné toutes les réponses du point de vue de la cohérence et de l'intégralité et en ont discuté avec les répondants, au besoin. RTM a également participé au calcul des estimations des coûts en capital et des frais d'exploitation à deux installations productrices.

Il n'y a présentement que trois provinces qui appliquent des normes identiques ou équivalentes à celles établies par l'Office des normes générales du Canada (ONGC), lesquelles permettent maintenant une teneur maximale en soufre de 0,7% en masse pour les combustibles diesel de Type B, soit la plus importante catégorie de combustible diesel. L'industrie canadienne adhère cependant à une norme de 0,5% et il est possible qu'une nouvelle norme de l'ONGC égale à cette valeur entre en vigueur vers la fin de 1988.

La moyenne pondérée de la teneur en soufre des combustibles diesel des véhicules automobiles se situe actuellement à environ 0,2% en masse au Canada, mais elle varie entre 0,03 et 0,45, selon la raffinerie d'origine et la saison. Les considérations économiques exigent que toute mesure visant la réduction de la teneur en soufre des combustibles diesel de véhicules automobiles comporte la construction de nouvelles installations de raffinage qui réduiront également la teneur en soufre des combustibles

diesel destinés à d'autres usages (par exemple, dans les industries minières et forestières et dans les secteurs de transport ferroviaire et maritime) ainsi que des mazouts légers consommés au Canada. L'est du Canada constitue le marché principal du mazout léger en vrac. Il est possible dans cette partie du pays de séparer, dans une certaine mesure, les combustibles diesel des mazouts légers dans le cas de ventes locales et dans les principaux centres urbains situés dans le sud de l'Ontario et au Québec. Dans l'ouest du pays les ventes de mazouts légers sont peu importantes et, comme dans une bonne partie de l'est du pays, il n'existe pas suffisamment de réservoirs de stockage pour permettre la séparation des combustibles diesel et des mazouts légers.

Presque tous les répondants ont indiqué qu'il ne serait pas intéressant, du point de vue économique, d'assurer davantage de séparation dans l'ensemble du système. Pour chaque litre de combustible diesel de véhicules automobiles produit, on traite aussi, en moyenne, un litre environ de combustible diesel destiné à des usages non routiers et de mazout léger afin d'en arriver à un produit commun acceptable à titre de combustible diesel de véhicules automobiles et de combustibles diesel non routiers et de mazouts légers.

Cette enquête a supposé le maintien des tendances courantes de consommation du pétrole brut. Etant donné que l'enquête n'a pas tenté de considerer l'évolution possible de la consommation du pétrole brut, on n'a pas tenu compte de l'impact des pétroles bruts plus lourds, plus sulfurés et synthétiques qui seront substitués aux pétroles légers à faible teneur en soufre d'origine canadienne et étrangère au fur et à mesure que ces derniers deviennent plus difficiles à obtenir.

Presque toutes les raffineries sont en train d'entreprendre de grands projets en vue de l'élimination progressive du plomb tetraethyl de l'essence canadienne avant la fin de 1992. Bien qu'aucune date n'ait été fixée pour la réduction éventuelle de la teneur en soufre du combustible diesel au Canada, on s'attendrait à ce qu'une telle mesure soit coordonnée avec l'échéancier de 1991 et 1994 prévue pour les normes d'émissions des combustibles diesel par l'EPA aux Etats-Unis. Un tel échéancier provoquerait de la compétition avec le programme d'élimination du plomb de l'essence en ce qui concerne le personnel et les fonds. Dans l'ensemble, un préavis d'au moins quatre ans serait nécessaire pour mettre en oeuvre un programme de réduction de la teneur en soufre du combustible diesel de véhicules automobiles au Canada. Le programme global devrait accorder suffisamment de temps aux fabricants de moteurs diesel (et de capteurs d'échappement) d'optimiser leurs spécifications de design avant que les nouvelles spécifications relatives au soufre entrent en vigueur.

Deux petites raffineries qui on participé à l'enquête ont déclaré qu'afin de satisfaire à toute nouvelle spécification relative au combustible diesel de véhicules automobiles, il faudrait, compte tenu des considérations économiques, qu'ils achètent des composantes de mélange de combustibles diesel à teneur ultra-faible en soufre et(ou) vendent les composantes diesel existantes destinées à des usages non routiers. Il faudrait, en outre, acheter des combustibles diesel de qualité routière

pour satisfaire aux besoins locaux.

Bien que sept sur 25 des autres producteurs de combustibles diesel destinés au marché canadien, tous situés dans l'ouest du pays, satisfont à l'heure actuelle, ou pourrait satisfaire à un coût minime, à une norme de 0,05% en masse, la plupart des répondants seraient obligés de construire de nouvelles installations de traitement et(ou) d'effectuer des modifications majeures à leurs installations de désulfurisation existantes. Il y a un écart considérable entre les besoins en capital apparentés aux teneurs en soufre de 0,15 et de 0,05. Bien que la teneur maximale en soufre de 0,5% en masse, présentement respectée dans l'industrie, permet l'utilisation d'une certaine quantité de produits de première distillation, une spécification de 0,05% exigerait que toutes les composantes du combustible diesel (à l'exception de celles qui sont dérivées directement du pétrole synthétique) subissent l'hydrodésulfurisation.

Les nouvelles installations requises comprennent:

- les modifications à faire aux unités d'hydrodésulfurisation des distillats moyens;
- les nouveaux catalyseurs;
- l'augmentation de la capacité des réacteurs;
- l'augmentation de la capacité de recyclage du gaz;
- de nouvelles unités d'hydrosulfurisation fonctionnant à des températures et à des pressions supérieures à celles des unités existantes (conçues pour satisfaire à la norme de 0,5% en masse);
- des installations additionnelles de récupération d'hydrogène
- l'expansion et, dans certains cas, la construction de nouvelles installations de récupération du soufre;
- de nouveaux réservoirs de stockage intérimaire seront nécessaires dans au moins deux cas.

Les frais d'exploitation s'accroîtront en raison de l'emploi plus intense d'une quantité accrue de catalyseurs, de l'utilisation accrue de combustible utilisé au cours du traitement, des coûts d'entretien additionnels des nouvelles installations, d'un personnel opérationnel additionnel dans certains cas et des services de surveillance et de laboratoire accrus.

Le tableau 1-1(a) présente les coûts estimatifs, en dollars canadiens de 1987, de la réduction du soufre aux niveaux de 0,15 et de 0,05% en masse.

TABLEAU 1-1(a)

COUTS DE LA REDUCTION DE LA TENEUR EN SOUFRE DU COMBUSTIBLE DIESEL DE VEHICULES AUTOMOBILES

Niveau de spécification du soufre du combustible diesel de véhicules automobiles	Coûts en capital	Frais directs d'exploitation annuels	Coûts additionnels au point de vente*
% en masse	Millions de $ de 1987	Millions de $ de 1987	Cents par litre de combustible diesel de véhicules automobiles++
0,15	521,3	73,5	1,7
0,05	972,3	113,5	2,9

* Comprend des frais d'immobilisations annualisés representant, en moyenne, un taux de rendement V.A.N. d'environ 12% après déduction d'impôt

++ Suppose la consommation annuelle de 10 500 000 mètres cubes de combustible diesel de véhicules automobiles

* *Remarque: Basés sur une répartition régionale de la consommation du combustible diesel de véhicules automobiles de 58% dans l'est et de 42% dans l'ouest du Canada, les coûts régionaux dans le premier cas (0,15%) seraient de $0.023 le litre dans l'est et de $0.008 le litre dans l'ouest et dans le deuxième cas, (0,05), les chiffres correspondants seraient $0.038 dans l'est et $0.018 dans l'ouest.*

Les coûts estimatifs ne tiennent pas compte des possibilités de ventes supplémentaires ou d'une taxe sur la valeur ajoutée. Cependant, on a inclu une provision pour les impôts à payer sur le rendement du capital requis pour les nouvelles installations. Les coûts présentés ne comprennent pas les dépenses additionnelles que plusieurs producteurs auraient à engager pour acheter des combustibles diesel ou le pétrole brut à faible teneur en soufre au lieu de construire de nouvelles installations immobilières.

En ce qui a trait au cas 0,05, les coûts estimatifs par tonne de soufre récupéré en raison du changement de la spécification du combustible diesel de véhicules automobiles s'élèvent à environ $12 600 (voir l'annexe C).

A notre avis, il est probable que les utilisateurs non routiers des combustibles diesel et certains utilisateurs mazouts légers, surtout dans l'ouest et en dehors des grands centres urbains de l'est du pays, partageront les coûts additionnels en raison de la nature commune du produit et de la difficulté qu'on aurait à distinguer entre les usages routiers et les nombreux usages non routiers.

Le combustible diesel représente le plus important des frais d'exploitation des flottes de camions. Donc, l'économie canadienne en général et le secteur des transports en particulier feront face à des augmentations importantes des coûts.

Si la teneur maximale en soufre des combustibles diesel non routiers et des mazouts légers était réduite au même nouveau niveau que le combustible diesel de véhicules automobiles, cela engendrerait des coûts en capital et des frais d'exploitation sensiblement plus élevés que ceux exposés plus haut.

2.0 SURVEY

2.1 BACKGROUND

The U.S. Environmental Protection Agency has proposed technology forcing particulate emission standards to be met by new diesel engine systems, to take effect in 1988, 1991 and 1994, increasing in stringency with each step. Transport Canada has put in place standards that essentially match the first stage of the U.S. program. Current engine models can apparently meet the first level of emission standards but new engine models and/or additional equipment such as exhaust traps may be needed to meet subsequent standards.

In the United States, the Environmental Protection Agency is considering regulations which would also limit the allowable sulphur content of highway diesel fuel to as low as 0.05 percent by weight. At this time, U.S. and Canadian government and industry co-operative test programs are underway which will lead to much better understanding of the roles of sulphur (and aromatic) compounds on diesel engine particulate emissions under various load conditions for various models of diesel engines. Such tests should provide sufficient data for technically and economically sound Canadian decision making sometime in 1989.

In order to assess the cost impact on the Canadian refining industry of a possible reduction in the allowable sulphur content of Canadian diesel fuels, the Petroleum Association for Conservation of the Canadian Environment (PACE) has undertaken a survey of Canadian refiners.

At the time of contract award for this compilation, the survey form of Appendix B had been circulated to all Canadian diesel fuel producers. RTM collected the responses and reviewed the data. In one case, only verbal estimates were obtained for production rates. While an audit was not carried out of the response data, completeness of responses, sulphur levels and cost estimates were reviewed and discussed with individual refiners. In two cases, averages were developed from ranges provided by the producer and in two cases RTM assigned capital and operating costs, after the new unit sizes and certain operating parameters were provided by the diesel producer - in both cases the assigned costs used were slightly under the averages reported later in this report.

In several instances there is, and shortly will be more, pairing of refineries, with some transfer of intermediates from one refiner to another. In this report such refineries are treated as

independent refineries, although most, if not all, changes to allow production of low sulphur diesel fuel may occur only at one refinery of the pair.

The amount of highway diesel fuel has been estimated from Statistics Canada data[1] and estimates of on highway/off highway demands for each user category reported therein.

Tetraethyl lead will be phased out of Canadian gasolines at the same time as possible reductions in sulphur might become effective. Currently, Canadian refiners are in the midst of a wide variety of projects to accomplish this phasing out of lead; projects which, in themselves, will require very large expenditures of both capital and operating dollars and of technical personnel. Any near term program to reduce sulphur in diesel will, to a major extent, overlap the current gasoline oriented capital projects. Availability of both money and personnel will be very tight, and may extend the duration of a diesel fuel sulphur reduction program.

Diesel and light fuel oils are blended from a variety of crude oil middle distillate fractions, catalytically cracked stocks and/or their hydrotreated derivatives. The stocks too poor for blending into diesel fuels, but with generally higher heating value per litre and poor low temperature characteristics, are segregated in some refineries for blending with other stocks for home heating fuel oil (number 2 fuel oil). Generally, the lightest middle distillate fractions from crude oil are recovered and treated separately as they are mostly used for kerosene type jet fuel (Jet A) as well as being the major components of very low pour diesel, and very light fuel oil (number 1 fuel oil, the kerosene or stove oil of commerce). Diesel fuels are produced in up to ten seasonal grades serving northern as well as southern markets. Light fuel oil, when produced separately, is also blended in several seasonal grades.

Demand for home heating fuels such as light fuel oils - numbers 1 and 2 -is declining. In 1986 these represented about 34 percent of diesel and light fuel oil sales but are projected to drop to the order of 20 percent by the year 2000. (Ref.: Canadian Energy Supply and Demand 1985-2005, National Energy Board, October, 1986.) Western Canadian light fuel oil sales are already well below that level, so that most of the drop will occur in eastern Canada. The decline in light fuel oil sales will be approximately matched by rising diesel fuel and kerosene type jet fuel sales according to most industry predictions.

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1 Ref: (1) Refined Petroleum Products, Statistics Canada, Catalogue 45-004 monthly
(2) Quarterly Report on Energy Supply-Demand in Canada, Statistics Canada, Catalogue 57-003 Quarterly

TABLE 2.2-1

DEFINITIONS

TERM	DEFINITION	REFERENCES
Diesel Fuel	Distillate fuel used in high and medium speed internal combustion engines of the compression ignition type.	Cdn. General Stds. Board "Diesel Fuel" (current) Type AA (-51 C max. pour, 0.2 max. wt% sulphur) Type A (high speed automotive diesel) (-39 C max. pour, 0.5 max. wt% sulphur) Type B high speed automotive diesel with seasonally adjusted low temperature properties. May also be used in medium speed stationary engine applications (0.7 max. wt% sulphur). This is the diesel fuel most commonly used and referred to in this report. Statistics Canada - Diesel Fuel Oil groups AA, A and B
Highway Diesel Fuel	Diesel fuel used in vehicles travelling on highways and public roads	
Light Fuel Oil	Distillate fuel oils suitable for use in liquid-fuel-burning equipment without preheating.	CGSB - "Fuel Oil Heating" (current) Type 00 (-51 C max. pour, 0.2 max. wt% sulphur) Type 0 (satisfactory pour for storage/use, 0.5% sulphur) Type 1 (satisfactory pour for storage/use, 0.7% sulphur) Type 2 (satisfactory pour for storage/use, 0.7% wt% sulphur) Statistics Canada - Light Fuel Oil (#2 and #2) (c)
Stove Oil and Kerosene(d)	Distillate fuel oils similar to Type 00 (usually with more restrictive producers specifications).	Statistics Canada - "Stove Oil Kerosene" and "Kerosene and Stove Oil"

Note:
(a) Individual producers all have specifications equal or better than those of the CGSB - all use a maximum of 0.5 wt% for diesel fuels equivalent to Type B.
(b) Statistics Canada - data in Catalogues 45-004 and 57-003.
(c) Little #3 fuel oil sales - all production shown by Statistics Canada assumed as #2 (types noted above).
(d) "Av-Turbo Fuel Kero Type" as defined by Statistics Canada is similar to stove oil or kerosene but its production has not been considered in this survey.

In the refinery, highway diesel is not differentiated from the off road diesel used by natural resource companies - in surface mining (special diesels are produced for underground mining operations), oil and gas, and forestry industries in particular - and the construction industry. Normally there is also no differentiation of railroad or marine diesels from highway and off road diesel fuels although non highway uses represent about one third of all diesel fuels sold in Canada. Marine diesel fuels are blended from the same blending stock but generally have higher flash points - i.e. less of the more volatile diesel components.

According to Statistics Canada, approximately 3 percent of Canadian diesel and light fuel oil sales are of stove oil (also called kerosene and similar to number 1 fuel oil). At the refinery, stove oil is often produced and processed separately, but the bulk is blended into winter grades of diesel fuels and number 2 light fuel oil to provide the desired winter characteristics. In many cases, stove oil and the lowest pour ("arctic") diesel fuel are synonomous.

Currently, about 15 percent of the total of diesel and the number 2 light fuel oil production is segregated, almost all in certain eastern Canadian refineries, for light fuel oil sales in the regions of the refinery, and adjacent to related product pipelines serving major urban areas. In other parts of eastern Canada, and in all of western and northern Canada, diesel fuel and light fuel oils with the same pour (cold weather) characteristics are identical products taken from the same tank.

In eastern Canada there are extensive exports of light fuel oils, ranging in 1986 from 9 percent of light fuel oil production in Quebec, through 15 percent in Ontario to 38 percent in the Atlantic region. Canada earns very significant foreign exchange from such product exports. These light fuel oil exports are of higher pour point materials - i.e. poorer cold weather quality - than those required by Canadian markets.

Middle distillate hydrodesulphurization facilities at most refineries will have to be capable of processing essentially all diesel and light fuel oil components to meet the possible new highway diesel sulphur specifications for a number of reasons:

- the same raw material components are used in diesel and light fuel oils fuels,
- segregation of diesel and light fuel oil is expensive in terms of added tankage and inventory needs, in most cases more expensive than processing both diesel fuel and light fuel oil to a common specification,

- as light fuel oil demands decrease in eastern Canada, the advantages of the current partial segregation will gradually disappear, and
- summer sales of light fuel oils are low at a time of maximum diesel sales with the converse in the winter.

These factors indicate that any reduction of the sulphur specification of highway diesel fuel will be reflected in some reduction of sulphur contents of most "off road" diesel fuels and some light fuel oils, but not be to the same degree as with highway diesel fuels. Of the total of diesel and light fuel oil (numbers 1, 2 and 3) sales in 1986, roughly 45 percent was highway diesel - slightly over 10 million cubic meters.

There are no alternate approaches to sulphur reduction which are competitive with hydrodesulphurization and none are practiced in North America at this time. While appreciable research work is underway relative to catalytic hydrodesulphurization, no major short term breakthroughs are anticipated. In any case, currently available catalysts will be selected for any project started in the next two to three years.

In Canadian refineries, there already exist appreciable diesel and light fuel oil component catalytic hydrodesulphurization facilities - approximately 20% of crude capacity. However, these will be inadequate to meet the requirements of any new diesel sulphur reduction plan and new units will be needed. The new units will operate at higher temperatures and pressures than existing units, particularly if a 0.05 weight percent sulphur specification is applied. Such conditions will necessitate stronger and more corrosion resistant metals than exists in most units and capital costs for new facilities will be significantly higher.

The survey did not address the impacts of product imports and exports nor any difficulty that Canadian refiners may experience in recovering additional costs in a free market.

Although the NPRA survey[2] included a sub-case which considered the added costs to achieve a lowering of the aromatic contents of diesel fuel, such an extension was not included in this study.

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2 U.S. Refining Industry Capability to Manufacture Ultra Low Sulphur Diesel Fuels, National Petroleum Refiners Association, Washington, D.C. 1986

2.2 SURVEY METHODOLOGY

Appendix A provides a list of Canadian refineries and other plants contributing to Canadian diesel fuel production. The "Guidelines for Survey" as circulated by PACE to its members and to other Canadian refiners is also attached, as Appendix B.

Appendix C compares production estimates from the survey with 1986 Statistics Canada production data. A closure of approximately 94% is indicated, which is considered acceptable for the purposes of this survey. It will be noted that there are transfers from stove oil/kerosene to diesel fuel and from diesel plus unsegregated light fuel oil to light fuel oil in systems downstream of producers.

The accuracy of the average sulphur content of 1987 Canadian diesel fuels as noted above is considered to be approximately ±5% - i.e. between 0.19 and 0.21 weight percent. Seasonal variances in demand, processing stability and crude type availability have been considered in this estimate.

In addition to the 25 refineries producing diesel fuels, the Suncor oil sands plant and the Polysar ethylene plant have been included, as both contribute to gross Canadian diesel production. Where crude capacities of Canadian refineries are totaled, the Polysar facilities crude usage is included; but, as the majority of Suncor's production is of synthetic crude oil, the bitumen feed at that plant is not considered in crude totals. Two western refineries which produce only asphalt have been excluded from the survey. The Newfoundland Processing facility at Come-by-Chance has not been included, being considered strictly an export refinery.

Imported diesel fuels have not been considered, but some diesel fuel exports may have been included as new facility needs were considered by certain refiners.

The survey results have been compiled by RTM in order to insure no transfer of data between companies. The responses reflect the estimated cost to meet the proposed standards. Economic decisions for continued operation under these conditions were not considered in the survey.

The survey results are in current 1987 cost terms. The survey has taken into consideration all announced expansion and/or revision projects that will affect highway diesel fuel sulphur content. The cost data do not include any allowances for interest during construction and additions to working capital, nor do they include inflation in any aspect. Conversion from capital

expenditures to capital charges per litre of product has been made at a rate of 20 percent before tax which provides approximately a 12 percent after tax return on investment for major integrated refiners. Depreciation and amortization have not been considered other than relative to taxation.

Where applicable, added segregation of middle distillate blending components used for diesel, light fuel oils and turbine fuels has been assumed acceptable. The cost per litre of a new highway diesel fuel sulphur level is assumed to be borne only by highway diesel. Due to the lack of diesel and light fuel oil segregation in many refineries, the average sulphur level of non highway diesel fuels and light fuel oils will fall when new diesel oriented desulphurization facilities are installed. No credit has been considered for possible higher non highway diesel and light fuel oil prices. But likewise, it is to be noted that capital and operating costs reflect only a decrease in the allowable sulphur in highway diesel; reduction of sulphur specification in other fuels (light fuel oil, stove oil etc.) will necessitate added capital and operating costs beyond those indicated herein.

2.3 CURRENT SITUATION

The survey data indicated that the current Canadian annual average diesel fuel sulphur content is approximately 0.20 percent by weight. The sulphur content level varies with overall product demands and with certain quality parameters as they change seasonally and with crude types and sulphur levels. For example, most asphalt is produced in warm months from heavy high sulphur crudes contributing more sulphur to middle distillates than is the case in winter. There are often other unscheduled changes, due to short term variations in the quality of most crude blends and unavailability at times of certain low sulphur conventional and synthetic crude oils.

A U.S. 1986 survey showed an average diesel fuel sulphur content of 0.27 weight percent. The lower Canadian level is principally due to the demand here for significantly more low temperature grades of diesel fuels, which are derived from lighter, lower sulphur components. Use of low sulphur synthetic crude and low sulphur conventional crude feedstocks also contributes to lower sulphur in diesel fuels, especially in western Canada. Tables 2.3-1 and -2 provide a review of average diesel fuel sulphur content by refinery size and location. Figure 2.3-1 and Figure 2.3-2 provide an overview of the average sulphur distribution in current Canadian diesels. The curve has been smoothed to avoid discontinuities and because it is cumulative, does not pass through the weighted mean sulphur content at the 50% volume point. Monthly averages vary appreciably from the annual average with the average increasing in summer, as heavier, higher sulphur components are used, and decreasing in winter. However, in no case will the maximum industry standard of 0.5 weight percent be exceeded.

In western Canada, there is very little segregation of diesel fuels and light fuel oils, but up to 8 seasonal grades of dual purpose diesel/light fuel oil may be produced in any one refinery over a year to satisfy both local and remote markets. In eastern Canada, several refiners segregate diesel fuel from light fuel oils for sales of light fuel oil in export markets and in the regions adjacent to the refinery and to related product pipelines - e.g. in major urban centers.

The amount of segregation of light fuel oil from "diesel" is in the order of 15 percent of the total of diesel fuel and (number 2) light fuel oil production, virtually all in eastern Canada. Exports of light fuel oil have continued at a high level in the first 8 months of 1987, repeating the 1986 pattern with the majority of exports again being from the Atlantic provinces. No segregation of diesel fuel was identified for off road vehicle use, but some minor segregation is practiced relative to railway and marine diesel fuels in the order of 2 to 4 percent of total diesel fuel sales.

The low sulphur level of western Canadian diesels is due to the use of the majority of current synthetic crude production (which is not only very low in sulphur but is also high in diesel component yield) and due to the availability of local low sulphur crude oils. In eastern Canada, higher sulphur crude oils are much more common resulting in higher diesel sulphur levels.

TABLE 2.3-1
CURRENT DIESEL SULPHUR BY PRODUCER SIZE

	FACILITY SIZE m^3/cd (BPCD)			
Current** Avg. Diesel Sulphur (wt %)	0 to 4770 (0 to 30,000)	4770 to 15,900 (30,000 to 100,000)	15900 (100,000+)	Total
0.00 to 0.05	1	3	1	5
0.06 to 0.15	3	1	1	5
0.16 to 0.25	3	3	3	9
0.25 plus	0	7	1	8
TOTAL	7	14	6	27

**Anticipates process configuration changes to be implemented in 1988 at two refineries

TABLE 2.3-2
CURRENT SULPHUR DISTRIBUTION BY PRODUCER LOCATION

	REGION				
Current** Avg. Diesel Sulphur (wt %)	B.C. (& NWT)	Prairies	Ontario	Quebec & Atlantic*	Total
0.00 to 0.05	1	4	0	0	5
0.06 to 0.15	2	2	1	0	5
0.16 to 0.25	2	1	2	4	9
0.25 to 0.45	2	0	4	2	8
TOTAL	7	7	7	6	27

Note: * Combined due to limited number of producers in each region.
** Anticipates process configuration changes to be implemented in 1988 at two refineries.

Canadian refiners currently produce diesel fuels meeting or exceeding the Canada National Standard specifications of the Canadian General Standards Board (CGSB). In the case of summer diesel fuels, the refiners all have a sulphur maximum specification of 0.5 weight percent although the current CGSB standard has a specification of 0.7 weight percent maximum. A draft of a new specification is now being circulated to CGSB committee members which includes a 0.5 sulphur specification for grade B, which is used in most parts of the country outside the coldest months. Adoption of the proposed specification is expected during 1988.

The CGSB diesel fuel standards have been accepted directly or in very similar provincal standards by only Ontario, Nova Scotia and Quebec, other provinces have yet to adopt any diesel fuel standards.

FIG. 2.3-1

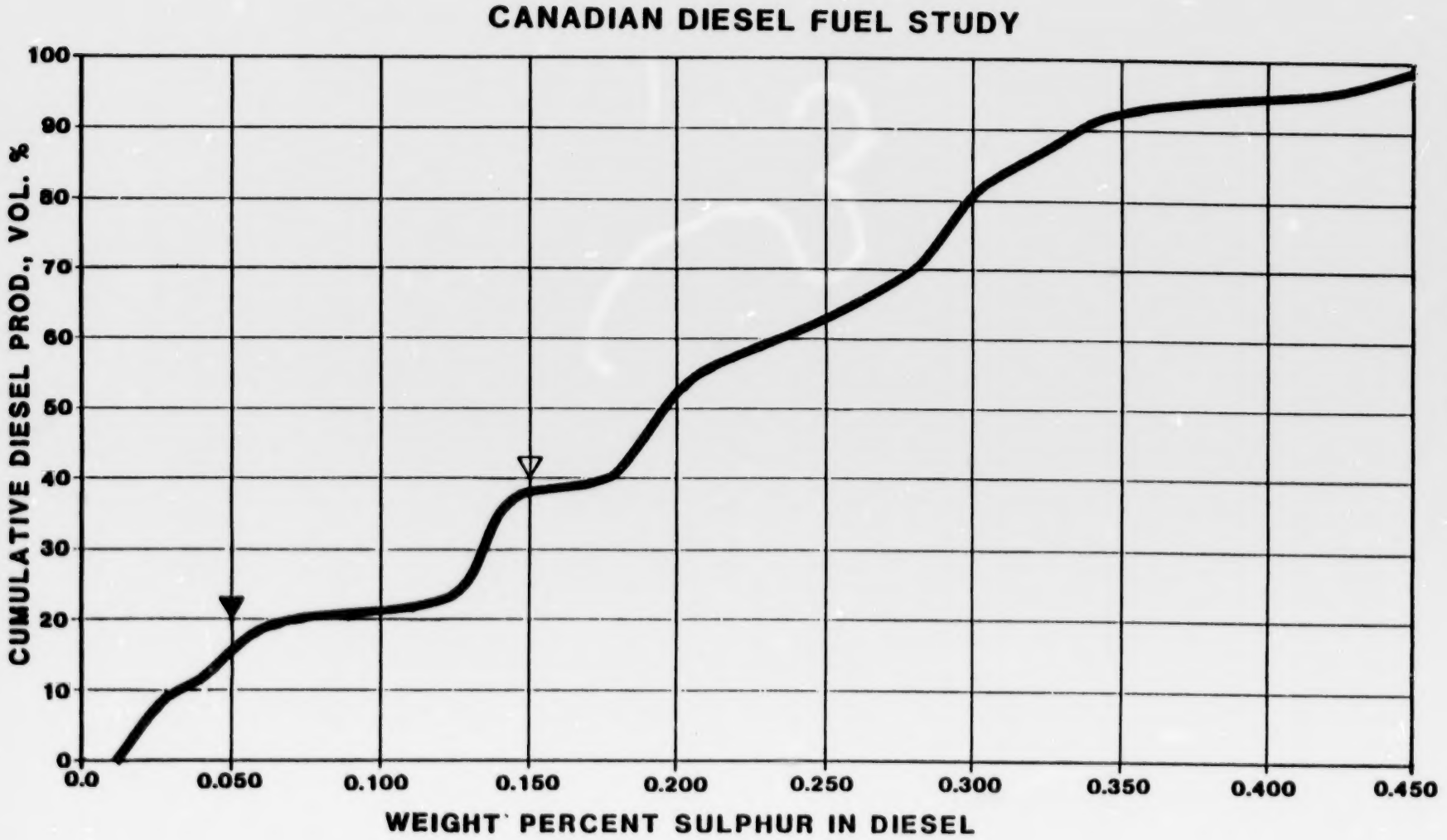
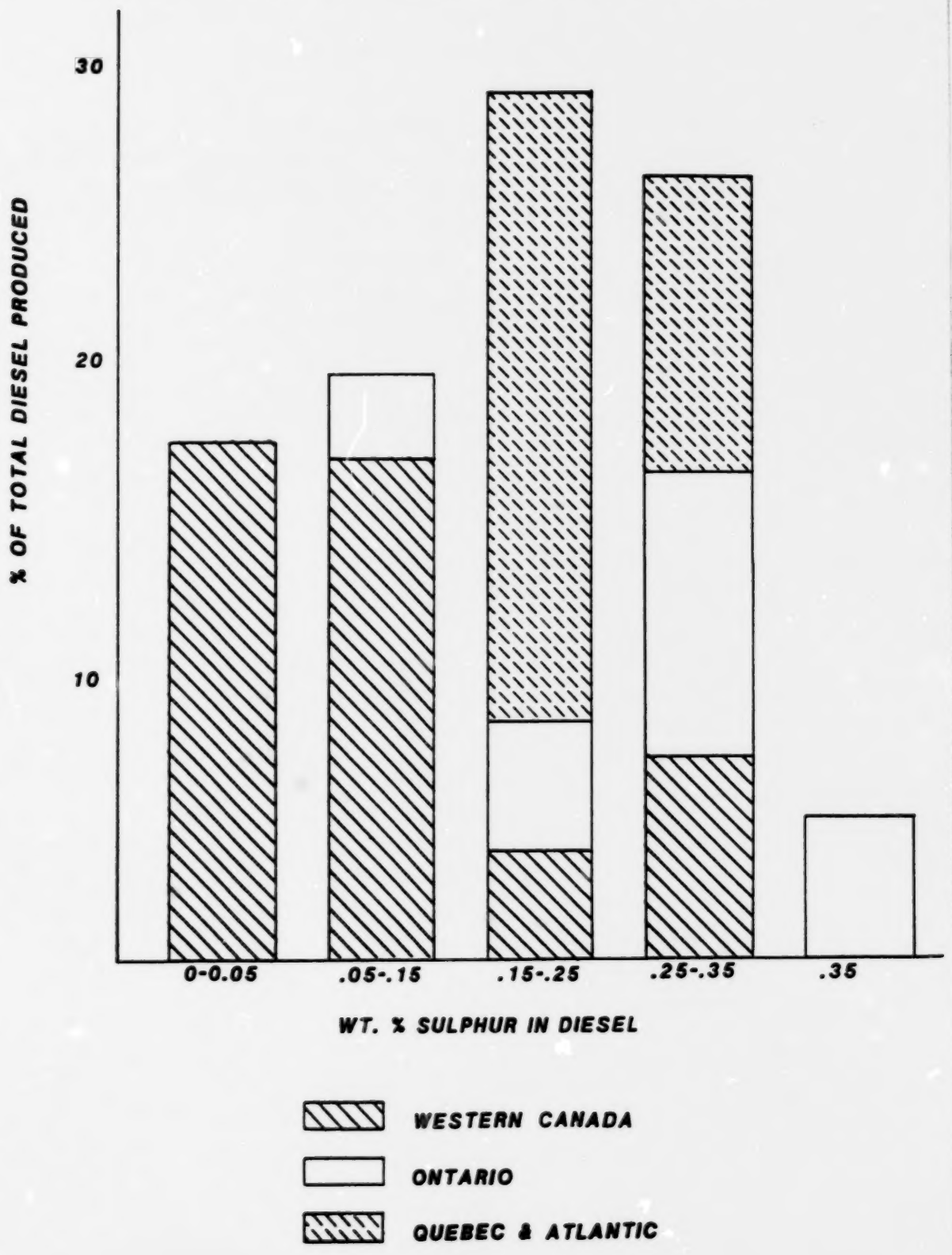

CANADIAN DIESEL FUEL STUDY
CUMULATIVE DIESEL PROD., VOL. %
100
90
80
70
60
50
40
30
20
10
0
0.0
0.050
0.100
0.150
0.200
0.250
0.300
0.350
0.400
0.450
WEIGHT PERCENT SULPHUR IN DIESEL

FIG. 2.3-2

SULPHUR CONTENT OF DIESEL FUEL BY REGION



2.4 COSTS

Table 2.4-1 summarizes the number of refineries requiring changes in order to meet possible new sulphur specifications. Changes costing less than $3 million have been considered minor.

TABLE 2.4-1
SUMMARY OF PRODUCERS REQUIRING CHANGES
No. of Producers
(% Diesel Production Capacity)

Future Diesel Sulphur Specification (wt.%)	No Change	Change Crude or Buy Highway Diesel	Minor** Capital	Major Changes
0.15	9 (36)	2 (2)	2 (14)	14 (48)
0.05	5 (13)	2 (<1)	2 (3)	18 (84)

** Below 3 million dollars

The last column includes refineries which produce diesel having an average sulphur content within the specification but which require added diesel desulphurization capacity in order to operate satisfactorily all year with changing product demands and normal crude quality variations. In practice, the number of such producers may be underestimated, given the non definable probability of future changes in crude availability, relative pricing, and quality.

As can be seen from Table 2.3-2, Prairie refineries generally require little change to meet a possible new sulphur specification. In British Columbia, half of the refineries face major work at 0.15 and all but one at the 0.05 level. In eastern Canada, only one refiner will not require major change at the 0.15 level; but even he will require a new unit at the 0.05 level.

Firstly, the 0.15 level is considered from a cost viewpoint:

TABLE 2.4-2
COSTS ASSOCIATED WITH A 0.15% SULPHUR SPECIFICATION
- in millions of 1987 dollars -

Region	Capital Requirements	Operating Costs**	Capital Recovery+	Total to Consumer
Western Canada*	102.8	16.5	--	--
Ontario	222.2	29.0	--	--
Quebec	143.1	16.1	--	--
Atlantic	53.2	11.9	--	--
TOTAL	521.3	73.5	104.3	177.8

Notes:
* Includes British Columbia, NWT and Prairies (all capital requirements restricted to B.C.)
** Cash costs only - no capital recovery included
\+ At 20 percent before tax and depreciation, etc. - equivalent to about 12% DCF rate of return after income tax

The above understates the total cost to some extent as the costs of purchasing highway diesel fuel at one producer and better crude at another are not included. Due to very significant interregional transfers, no regional breakdown of "capital recovery" or "total to consumer" is provided - charges are expected to be spread across all Canadian highway diesel fuel consumers. There will be a marked tendency for higher costs in eastern Canada due to the predominance of capital expenditure being in that area.

Assuming 10,500,000 cubic meters a year of highway diesel fuel, the incremental cost to a consumer will rise by an average of about 1.7 cents per litre at a new 0.15 sulphur specification level (see Table 1-1). In our opinion, it may prove very difficult for the refiner to allocate the costs of such a program to only highway diesel fuel users.

At the 0.05 level, the costs rise as shown below:

TABLE 2.4-3
COSTS ASSOCIATED WITH A 0.05% SULPHUR SPECIFICATION
- in millions of 1987 dollars

Region	Capital Requirements	Operating Costs**	Capital Recovery+	Total to Consumer
Western Canada*	216.9	35.7	–	–
Ontario	408.0	36.3	–	–
Quebec	164.4	18.4	–	–
Atlantic	183.0	23.1	–	–
TOTAL	972.3	113.5	194.5	308.0

* Includes British Columbia, NWT and Prairies (63% of regional capital requirements required in B.C.)
** Cash costs only - no capital recovery included
\+ At 20 percent before tax and depreciation, etc. - equivalent to about 12% DCF rate of return after taxes

Again, the table probably understates the total cost for the reasons noted above. In the 0.05 case, the incremental cost to the average Canadian highway diesel fuel user will be 2.9 cents per litre. There will be larger increases in eastern Canada due to the large portion of capital requirements there.

In only one refinery were "added segregation" facilities for diesel and light fuel oils noted as being planned.

Major changes that have been identified are as follows:

TABLE 2.4-4
MAJOR CHANGE SUMMARY

	wt% Diesel Sulphur Specification	
Major Change	0.15	0.05
New Hydrodesulphurization Units (total capacity)	12 (22,000 m^3/d)	18 (34,000 m^3/d)
Extensive Revisions to Existing HDS Facilities	7	6
Hydrogen Synthesis Unit	-	1
New Sulphur Plant	1	2

Note: Does not consider any changes in emission standards.

Revisions to existing hydrodesulphurizers will involve new reactors, new recycle gas systems, new feed fractionators and/or new catalyst, the latter common to virtually all existing refineries. In virtually all cases, revisions will be required to existing amine treating, sour water stripping and H_2S to sulphur recovery units. New hydrogen recovery systems will be needed in several cases but need for new production facilities has been indicated only in one refinery. New tankage is also needed in many cases.

It is to be noted that the capital and operating costs discussed above cover only costs associated with reducing the sulphur content of diesel fuels. While some parallel reduction in the sulphur content of light fuel oils due to the use of common facilities and the commonality of intermediates will occur, there will be very significant further expenditures required if the allowable sulphur content of all diesels and light fuel oils is reduced to the same new standard.

2.5 TIMING AND CONSTRAINTS

In 1987, approximately 35 percent of Canadian gasoline contains lead. By the end of 1992, such sales will be phased out. It is also to be noted that the percentage sales of premium grades of gasoline have escalated rapidly in the past two years and the trend is continuing, putting even more pressure on refiners to increase the octane capabilities of their refineries. Every gasoline producing refinery in Canada will require some facility change and/or additions as lead is phased out and this means major expenditures over the next four years. A number of such projects are already well underway.

If new specifications for the sulphur content of highway diesel fuel were to come into effect before 1996, there would be a large overlap with the gasoline octane program. Lead times of four years or more have been estimated by many respondents as being required to allow for facility planning, corporate budgeting, bid preparation, engineering, procurement and construction, commission and startup of new and revised facilities. The new and revised facilities will include sulphur recovery in virtually all cases, but no serious constraints or above normal delays relative to environmental permitting have been noted in this survey. The installation of new facilities must be programmed to allow unhindered operation of existing facilities and, thus, changes and connections to existing facilities can only be done at one or two times of the year. The situation is further complicated by the commitment of much technical and planning manpower to the gasoline octane program.

This study has not examined the ability of the equipment fabrication, engineering and construction industries to meet the possible schedules. Further analysis in that regard appears required in order to confirm that the four year lead time is achievable.

The gasoline programs themselves require very major funding and this will impact on the availability of funds needed by a diesel fuel sulphur reduction program. In this survey, we did not note any refiner unable, in the long run, provided the costs could be recovered in the market place, to finance a diesel sulphur reduction program. This is unlike the response to a U.S. survey where 27 percent of refineries said they would not be able to finance or otherwise would be unable to complete the needed work at the 0.05 percent sulphur level. But constraints on availability of funds, possibly necessitating a stretched out program were noted by several respondents. Shutdown of refineries would continue as an option.

A staged approach to a new low level diesel sulphur specification was considered by at least one respondent and could form an attractive means of deferring some investment to a later date. In such an approach, new units necessitated by the first stage specification would be built in such a manner as to readily accommodate later revision to the final specification. At the several refineries needing two new hydrodesulphurization units for the 0.05 level, there would be the opportunity to defer the second unit to the final stage. Such a staged approach would not decrease the total expenditure needed but would provide a more manageable cash flow in certain instances.

A staged approach would also provide diesel engine (and trap) manufacturers time to fully develop their new design concepts to provide a more optimized engine/fuel system development. Given current low average concentrations and the downward trend, it has been suggested that consideration should be given to doing nothing until the engine system manufacturers catch up with new technology.

At least a four year lead time appears essential in any future diesel fuel sulphur specification program.

APPENDIX A

CANADIAN DIESEL FUEL PRODUCERS

REGION	PROVINCE TERRITORY	PLACE	REFINERY	CRUDE CAPACITY m^3/d(1)	NOTES
British Columbia	N.W.T.	Norman Wells	Esso Petroleum	500	Simple Distillation Only
	B.C.	Taylor	PetroCanada	2,810	
	B.C.	Prince George	Husky	1,500	
	B.C.	IOCO	Esso Petroleum	6,800	
	B.C.	Pt. Moody	PetroCanada	5,910	(2)
	B.C.	Burnaby	Chevron	5,700	
	B.C.	Burnaby	Shell	3,820	(3)
Prairies	Alberta	Tar Island	Suncor	N.A.	Oil Sand Processor with Diesel Byproduct
	Alberta	Ft. Saskatchewan	Shell	8,900	Synthetic Crude Oil only feed
	Alberta	Edmonton	Esso	26,200	
	Alberta	Edmonton	PetroCanada	19,250	
	Alberta	Bowden	Parkland	800	Pentanes Plus Feed
	Alberta	Calgary	Turbo	4,390	
	Saskatchewan	Regina	Cons. Co-op	5,725	(4)
Ontario	Ontario	Sarnia	Esso	19,600	
	Ontario	Sarnia	Suncor	11,130	
	Ontario	Sarnia	Shell	11,300	
	Ontario	Sarnia	Polysar	7,200	Ethylene Producer (5)
	Ontario	Nanticoke	Texaco	15,100	
	Ontario	Oakville	PetroCanada	12,800	
	Ontario	Clarkson	PetroCanada	9,540	
Quebec	Quebec	Montreal	PetroCanada	13,500	
	Quebec	Montreal	Shell	19,080	
	Quebec	Quebec City	Ultramar	16,380	
Atlantic	New Brunswick	St. John	Irving	37,760	
	Nova Scotia	Dartmouth	Esso Petroleum	13,100	
	Nova Scotia	Dartmouth	Texaco	3,180	
TOTAL				281,975 (1,773,500 BPCD)	(6) (7)

Notes:

(1) Oilweek June 8, 1987, except estimate for Polysar capacity, calendar day figures.

(2) Will process by late '88 semi processed stream from Alberta refinery.

(3) Processes in part semiprocessed stream from Alberta refinery.

(4) About 7200 m^3/d of heavy crude in late 1988 to associated NewGrade upgrader, refining capacity, per se, assumed unchanged.

(5) Nominal capacity - crude intake varies with economics of alternate feeds.

(6) Excludes asphalt only refineries at Lloydminster and Moose Jaw. ("TOPS" - all crude components lighter than asphalt - go to Ontario refineries)

(7) Excludes Newfoundland Processing at Come-by-Chance - assumed export refinery

APPENDIX B

GUIDELINES FOR SURVEY

REFINERY IDENTIFICATION SHEET FOR PACE DIESEL FUEL SURVEY

Company: _____

Refinery Name: _____

Refinery Location: _____

Company/Refinery Point of Contact _____ (Name)

_____ (Telephone)

The following is a list of assumptions and case criteria which should be incorporated into all of the studies:

1) Base Case: Each company should assume this to be the status quo. For the defined time frame, the company's crude slate, product demands and product specifications should be as per their strategic plan. The maximum sulphur content in the diesel should remain unchanged at 0.5 wt%. Distillate product volumes and qualities should be shown.

2) Time Frame: The period of 1988 to 1995.

3) Crude Slate: The crude slate used should be the one which is forecasted by each refiner. In the case where a crude slate change is made to meet a reduced sulphur specification, the increased operating expense and the % change in the crude slate volumes should be noted.

4) Product Slate: It should be noted that segregation of a premium diesel fuel for road transport will not be considered as an option at this time. It will be assumed that the entire diesel volume is produced to the required sulphur specification.

5) Product Specification: The sulphur content of all distillate products should be stated. If the data is available, the aromatics content of the diesel fuel should be stated for all cases.

6) Costs: All operating costs should be stated in 1987 dollars. When increases in operating costs are incurred, the costs should be broken down in detail to indicate those which resulted from having to run a more expensive crude, increased fuel costs to operating an additional processing unit and increased chemical costs.

7) Capital investment: Dollars for capital investment should be stated in current (1987) dollars as well as in spent dollars. A breakdown of the type of investment, i.e. additional hydrotreating capacity, additional sulphur recovery units and associated amine treating facilities or a hydrogen production unit, should be indicated. Since no target dates for sulphur reduction have been established, each refiner is requested to provide the required lead times for capital investment.

   The refiner is requested to provide the sulphur level at which major capital investment becomes a requirement. This will vary for each refiner depending upon the refiner's process configuration, crude and product slates.

The cases which have been selected for study are as follows:

(a) Base case - as defined above. If the sulphur level of diesel in the base case is significantly higher than 0.25 wt%, the refiner may want to run a case at this limit (optional case).

(b) Maximum sulphur content of diesel to be 0.15 wt%.

(c) Maximum sulphur content of diesel to be 0.05 wt%.

APPENDIX C

MISCELLANEOUS CALCULATIONS AND BALANCES

A. UNIT COST OF SULPHUR REMOVED AND RECOVERED AT 0.05 SPECIFICATION

	Vol. 103m3/Yr.	Sulphur Reduction	Assumed S.G.	Sulphur Recovered (tonnes/Yr.) Gross	Net @ 96%
Diesel (+ some L.F.O.)	18,650	0.20 to 0.04	.842	25125	24120
Stove Oil to Diesel (approx.)	477	0.12 to 0.04	.810	309	297
TOTAL				25434	24417

Annual Costs - $308,000,000 (Table 2.4-3)

Cost per tonne of Sulphur removed and recovered - $12,600

B. COMPONENT BALANCE CHECK (10^3m^3/Yr.)

	Reported Production This Study	1986 Production(a)
Stove Oil Kerosene	1163	563
Diesel + Unseg. L.F.O.	18650	15272
Lt. Fuel Oil	3344(b)	8730 (c)
Totals	23157	24565
Shortfall	1408 (6.1%)	

Notes: (a) Statistics Canada "Refined Petroleum Products", Catalogue No. 45-004, line #3 net production.
(b) 15.2% of Diesel + L.F.O.
(c) Significant transfers to diesel and light fuel oil shown.